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Supplier Selection by Considering Cost and Reliability

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***Abstract*—**Supplier selection problem is one of the important issues of supply chain problems. Two categories of methodologies include qualitative and quantitative approaches which can be applied to supplier selection problems. However, due to the complexities of the problem and lacking of reliable and quantitative data, qualitative approaches are more than quantitative approaches. This study considers operational cost and supplier's reliability factor and solves the problem by using a quantitative approach. A mixed integer programming model is the primary analytic tool. Analyses of different scenarios with variable cost and reliability structures show that the effectiveness of this approach to the supplier selection problem.

***Keywords*—**Mixed integer programming, quantitative approach, supplier's reliability, supplier selection.

I. Introduction

CUSTOMER demand is one of essential driving forces for a supply chain. For fulfilling the customers' demand and satisfaction, a company has to manage its supply chain efficiently and effectively, including products' material supplies, production, distribution, transportation. The implication of effectiveness and efficiency on logistic operations is that a company pursues profit to keep its sustainability. Profit comes from revenue should be larger than cost. This study considers two factors that relate revenue and cost. The revenue positively relates to the material supply reliability, and the costs include material cost, purchasing setup cost, and shortage penalty cost. In this study, these two factors are main determinants of the objective/performance of the mathematical model establishment.

The starting point of a supply chain is material delivery. The material cost takes a large proportion of the product costs; 70% in common goods, and even reaching 80% in high-tech products [1]. That indicates costs due to suppliers are important issues for a company. [2] concluded material cost is not the only concern for an enterprise's competence, vendor selection also needs to be considered one of core competencies of a company. [3] summarized 14 essential considerations when a company chooses suppliers, which are shown in Table I. According to [3], the two factors, cost and reliability, that are used in this study are consistent. However, regarding the cost, this study adds one extra cost, purchasing setup cost, which is the processing cost of a company to do the business with a supplier.

In the past, researchers applied various approaches to study the vendor selection problem, in which [1], [4]-[7] systematically reviewed references. [4] gathered statistics of published papers after 2008 in the popular databases, including Science Direct, Emerald, Springer-Link Journals, IEEE Xplore, Academic Search Premier, and World Scientific Net. [4] found the most related 123 papers and analyzed the research contents of those papers. There are 26 solution approaches in total, and 6 of those are the most applied approaches, including AHP (Analytic Hierarchy process), ANP (Analytic network process), TOPSIS (Technique for order performance by similarity to ideal solution), DEA (Data Envelopment Analysis), LP (Linear Programming), MOP (Multiobjective programming).

TABLE I
CONSIDERATIONS FOR CHOOSING A SUPPLIER. COST AND RISK ARE TWO ESSENTIAL FACTORS CONSIDERED IN THIS STUDY

Criterion	Attribute	Definition
Delivery	Accuracy	Accuracy in meeting the promised delivery time
	Capacity	Capacity of the supplier
	Lead Time	Promised delivery lead time
Business Performance	Financial status	Financial performance
	Compatibility of business strategy	Compatibility of strategic plans of the suppliers with buyer's long term plans
Quality	Defective rate	Rate of defective items among shipped
	Responsivenes s	Reaction time of supplier to correct defects and other supply related issues
Cost	Unit cost	Cost per item
	Order change and cancellation charges	Fees associated with modifying or cancelling orders after placement
Information Technology	Online	Availability of online ordering and order tracking
	EDI	Availability of EDI systems at the supplier
Long term improvement	Improvement programs	Improvement of customer service related activities at the supplier
	R&D activities	Incentive in pursuing R&D
Risk (Reliability)	Risk score	Risk due to supply disruption

Reproduced from Table I of [3].

The principle of AHP is to divide a complex problem into a hierarchy structure. Within each level, a relative importance of pairwise factors is evaluated by experts. By a matrix calculation, a weight of factor can be determined. However, consistency of the factors' evaluations by different experts becomes critical. [8] applied AHP to evaluate and rank potential suppliers and provided a realistic case application with several criteria of supply reliability. The factors for AHP in a hierarchy structure are assumed independent of each other. However, some factors might be dependent on each other. Therefore, ANP was developed to conquer the factors' dependent issue. An example of ANP application is [9] applying ANP in supplier selection for an electronic company case. Generally, TOPSIS needs to

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work with other approaches to determine an ideal positive and negative solutions. The evaluated plans are tried to be close to the ideal positive solution and away from the ideal negative solution. [10] combined fuzzy and TOPSIS forming multi-criteria analysis to solve the supplier selection problem. DEA is applied for determining the total efficiency of different DMUs (Decision Making Unit). Entire efficiency is defined the ratio between a weighted sum of outputs and weighted sum of inputs, which is shown in (1).

$$\text{Efficiency} = \frac{\sum_{\forall j} w_j O_j}{\sum_{\forall i} w_i O_i} \quad (1)$$

in which, i is index of inputs; j is index of outputs; w_i is weight of i^{th} input (I_i);w_j is weight of j^{th} output (O_j).

By using LP maximizing (1), an entire optimal efficiency can be defined. [11] used DEA to evaluate the five performance indicators of 18 suppliers, including supply variance, quality, supplier distance, delivery rate, price. Some tools can be applied at the same time, such as [12] and [13] combined AHP and DEA to solve the supplier selection problem. LP and MOP are solved by determining decision variables with an objective (objectives) and corresponding constraints. [14] applied a scenario tree concept and a mixed integer program to solve the supplier selection problem with considering reliability. To the best of my knowledge, [14] is one of few studies to apply MIP mathematical model considering reliability on the supplier selection problem. However, because of the computational complexity of the solution approach in [14], the instance that provided [14] was a small size example with considering one commodity and five suppliers. [15] established a multi-item supplier selection model with bi-objectives (profit and risk) and applied multi-objective genetic algorithm (MOGA) to solve the model. Because the model is bi-objective, it is hard to solve the model optimally by MOGA. This study tackles the supplier selection problem with considering two important factors, i.e. cost and reliability mentioned in Table I. The solution approach is to establish a MIP model. Instead of putting reliability into an objective function, this study puts reliability into a constraint. The purpose of the model is to pursue the maximal supplier reliability but by setting the lower bound of the average reliability, results of supplier selection have to fulfill the minimal reliability. This way partly relaxes one objective and add one constraint, which makes the final solution become a feasible solution to the original problem. However, the advantage of this solution approach can use optimization Cplex solver to solve the problem.

The organizations of this study are as follows, Section I mentions the research motivation, popular solution approaches for the supplier selection problem, and the reasons that MIP model approach is adopted in this study. Section II introduce the solution framework, including MIP model and the steps to solve the problem. Section III demonstrates the capabilities of the solution approach by numerical results. Section IV concludes this study.

II. Solution Framework

A. Assumptions

In real world case, there are numbers of factors (Table I) influence supplier selection results. This study considers two main factors, cost and reliability. According to the parameter settings, results of supplier selection can be achieved by minimizing total cost, and the solutions are guaranteed that the minimal suppliers' reliability can be maintained. However, solutions come from the deterministic parameter settings. The chosen supplier might delay material delivery because of low supplier's reliability. Therefore, this study assumes that the chosen suppliers have chances to break on-time delivery promises. Although the supplier might break promises, the buyer will not change the supplier selection decisions until receiving all goods. In this scenario, a fixed time period, L, is introduced in the solution approach. Each L, the supplier that break material delivery promise has a chance to make up its backorder. The chance is determined by its reliability.

B. Mathematical Model

The details of the mathematical model are as follows, including indices, parameters, decision variables, and equations.

1. Index

i: supplier index
j: supplier's product index

2. Parameter

N: number of suppliers
K: number of products
M: a sufficient large number
RM: minimum requirement of average supply reliability
C_{ij}: unit cost of product j from supplier i
L_{ij}: $L_{ij} = 1$, supplier i sells product j, $L_{ij} = 0$, otherwise.
U_{ij}; upper limit quantities of product j that supplier i can sell.
P_j: penalty of shortage of product j
R_{ij}: reliability of product j from supplier i
F_{ij}: processing cost of component j from supplier i
D_j: Demand of product j

3. Decision Variables

z: ideal total cost
x_{ij}: quantities of product j from supplier i
y_{ij}: a binary variable. $y_{ij} = 1$, when product j from supplier i, $y_{ij} = 0$, otherwise
s_j: shortage quantities of product j

4. Equation

$$z = \min \sum_{i=1}^{N} \sum_{j=1}^{K} C_{ij} x_{ij} + \sum_{i=1}^{N} \sum_{j=1}^{K} F_{ij} y_{ij} + \sum_{j=1}^{K} P_j s_j \quad (2)$$

$$x_{ij} \le U_{ij} L_{ij} y_{ij} \quad \forall i, j \quad (3)$$

$$\sum_{i=1}^{N} x_{ij} + s_j \ge D_j \quad \forall j \quad (4)$$

$$s_{ij} \le M L_{ij} \quad \forall i, j \quad (5)$$

$$\sum_{i=1}^{N}\sum_{j=1}^{K} y_{ij}R_{ij} \,/\, \sum_{i=1}^{N}\sum_{j=1}^{K} y_{ij} \geq \text{MR} \quad (6)$$

Equation (2) represents an objective function, including three items. The first item is product cost, the second item is purchasing setup cost, and the third is the shortage cost due to the over-demand. Equation (3) indicates the relationship between the product demand quantity and decisions on supplier selection. Equation (4) represents the customer's demand has to be fulfilled. If over-demand happens, a shortage is allowed, which implies without s variable, the problem might be infeasible. Equation (5) ensures correct shortages from the right suppliers. Equation (6) guarantees the overall suppliers' reliability must be at least MR.

C. Problem Solution Steps

To solve the supplier selection problem, parameters need to be defined firstly, in which R_{ij} settings are different from other deterministic settings. Because fixed supplier's reliability is not reasonable R_{ij} in this study is assumed a normal distributed with a mean and a deviation. The second step is to execute repeatedly the model under different parameter settings until finishing all scenarios. The third step is to evaluate results and determine the qualified suppliers. Fig. 1 shows the flow of the solution approach in this study.

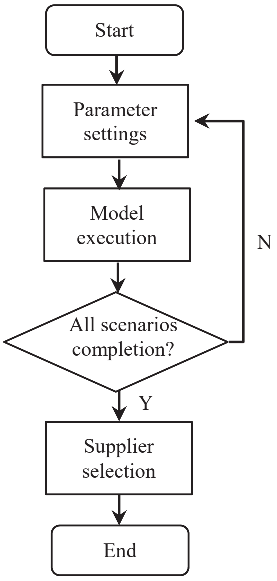

Fig. 1 The flowchart of the solution approach

D. Scenario Settings

In order to demonstrate the solution approach, a simulated case is used and described as follows. A company manufactures a kind of product, which needs 3 components, Type A, Type B and Type C. Type A product has highest cost and reliability. Type C product has lowest cost and reliability. The cost and reliability of Type B are between those of Type A and Type C products. 15 suppliers are providing three types' components. Suppliers are grouped into three as well, Group I, II, and III. Group I can sell three types' components. Group II cannot sell Type A component, but can sell Type B and Type C components. Group III can only sell Type C components. Three scenarios are for customer's demand, which are high, medium, and low demand. The definition of a high customer's demand indicates shortages of components occur frequently, a medium customer's demand refers shortages of components happen occasionally, and a lower customer's demand implies there is no shortage. The details of parameters are listed in the next section.

III. Computational Results

A. Numerical Experiments on Base Cases

In order to execute numerical experiments, indices and parameters have to be set in advance. Tables II and III show base case scenario settings. In base cases, all suppliers have the same reliability settings. Table II shows suppliers' product information, and Table III shows the details of cost, demand, capacity, and reliability parameters.

TABLE II
Supplier and Product Index Setting

	Group I	Group II	Group III
Supplier	$i = 1{,}2$	$i = 3, \cdots, 7$	$i = 8, \cdots, 15$
Product	A, B, C	B, C	C

TABLE III
Base Cases' Parameter Settings for Each Supplier

Product	Type A	Type B	Type C
Unit cost	100	10	1
processing cost	100	100	100
Penalty= Unit cost ×20%	20	2	0.2
Average Demand	High: 60 Medium:45 Low:30	High: 800 Medium: 600 Low: 400	High 6000 Medium: 4000 Low:2000
Capacity	25	100	400
Average Reliability (interval in 10%)	40% - 90%	40% - 90%	40% - 90%
Coefficient of Variation of Reliability	5%	5%	5%

By the settings of Tables II and III and (2)-(6), this study performs 450 numerical experiments. The results are in Figs. 1-3. Three indicators are calculated, including extra lead time due to unstable supplier reliability with maximum and average values, and additional cost due to supplier reliability. In figures, the symbols for the linear regression formula are x representing reliability, y indicating the indicators, and R representing correlation coefficient. These three number show that $x's$ and $y's$ are medium-correlated. Regression formula shows the trends of the indicators with reliability change.

B. Managerial Implications

Three figures show that three indicators have decreasing tendencies when the reliability increases. The variance under each reliability is getting small with increasing reliability. The overall trends make scenes in general. Under the parameter settings, standards for choosing supplier can be established. Fig. 2 shows that additional lead time of maximal value is 16, and the least value is 0. Type A, B, C are components for production. Additional lead time make the original production

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plan might be delayed which damages customers' satisfaction. Therefore, two-time period is set to be a standard. In this scenario, supplier reliability has to be larger 90%. However, all suppliers having reliability above 90% might be not realistic. If average lead time is set to be one-time period, from observations on Fig. 2, required supplier reliability can be set to 70%. From Fig. 3, if the supplier reliability is set to 90%, there might be additional 2% cost induced by supplier reliability, and if the supplier reliability is set to 70%, there might be additional 5% cost induced by supplier reliability.

According to the study results, if a strict standard is chosen, suppliers are selected with the reliability larger than 90%, which if a loose standard is taken into account, suppliers can be selected with the reliability larger than 70%.

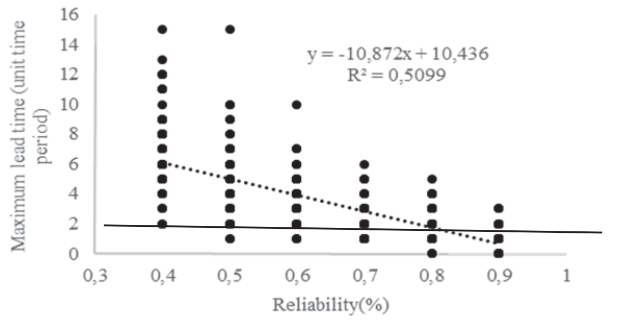

Fig. 2 Maximum lead time under different reliability

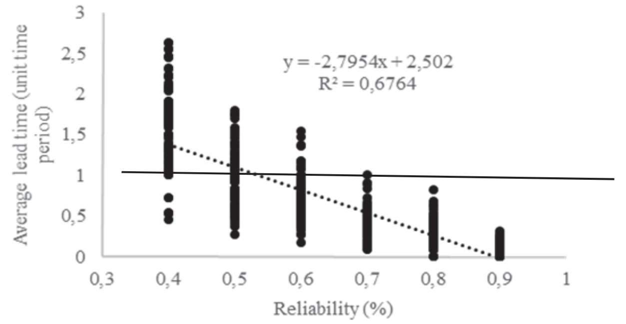

Fig. 3 Average lead time under different reliability

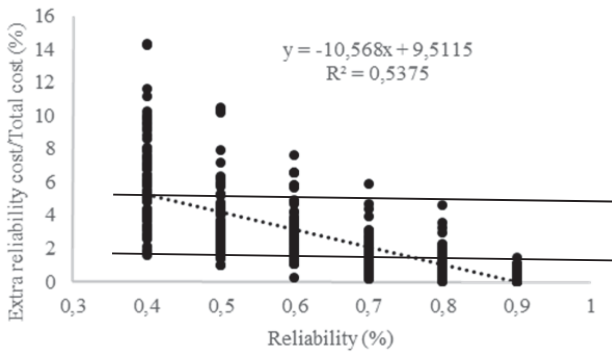

Fig. 4 Ratio of extra cost due to reliability and total cost

IV. Conclusions

In this study, a mathematical model is built for discussing cost and reliability performances of suppliers. Through the solution framework, suppliers can be selected accordingly. Quantitative approaches seldom consider reliability factor for choosing supplier. This study demonstrates the capabilities of the solution approach on solving the supplier selection problem.

Some possible suggestions for future studies; including bi-objective MIP for solving the problem, or more numerical scenarios with uncertain parameter setting making the solution approach into practical applications.

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References

[1] C. A. Weber, J. R. Current, and W.C. Benton, "Vendor selection criteria and methods," *European Journal of Operational Research*, vol. 50, 1991, pp. 2–18.
[2] S. H. Ghodsypour and C. Ó. Brien, "The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraint," *International Journal of Production Economics*, vol. 73, no. 1, 2001, pp. 15-27.
[3] A. Ravi Ravindran, R. Ufuk Bilsel, V. Wadhwa and T. Yang, "Risk adjusted multicriteria supplier selection models with applications," *International Journal of Production Research*, vol. 48, no. 2, 2010, pp. 405-424.
[4] J. Chai, J. N. K. Liu, and E. W. T. Ngai, "Application of decision-making techniques in supplier selection: A systematic review of literature," *Expert Systems with Applications*, vol. 40, 2013, pp. 3872-3885.
[5] W. Ho, X. Xu, and P.K. Dey, "Multi-criteria decision making approaches for supplier evaluation and selection: A literature review," *European Journal of Operational Research*, vol. 202, no. 1, 2010, pp. 16-24.
[6] Z. Degraeve, E. Labro, and F. Roodhooft, "An evalution of supplier selection methods from a total cost of ownership perspective," *European Journal of Operational Research*, vol. 125, no. 1, 2000, pp. 34-58.
[7] L. D. Boer, E. Labro, and P. Morlacchi, "A review of methods supporting supplier selection," *European Journal of Purchasing & Supply Management*, vol. 7, no. 2, 2001, pp. 75-89.
[8] R. R. Levary, "Using the analytic hierarchy process to rank foreign suppliers based on supply risks," *Computers & Industrial Engineering*, vol. 55, no. 2, 2008, pp. 535-542.
[9] C. Gencer and D. Gürpinar, "Analytic network process in supplier selection: A case study in an electronic firm," *Applied Mathematical Modelling*, vol. 31, no. 11, 2007, pp. 2475-2486.
[10] C. -T. Chen, C.-T. Lin, and S.-F. Huang, "A fuzzy approach for supplier evaluation and selection in supply chain management," *International Journal of Production Economics*, vol. 102, 2006, pp. 289-301.
[11] W. L. Ng, "An efficient and simple model for multiple criteria supplier selection problem," *European Journal of Operational Research*, vol. 186, 2008, pp. 1059-1067.
[12] R. Ramanathan, "Supplier selection problem: integrating DEA with the approaches of total cost of ownership and AHP," *Supply Chain Management: An International Journal*, vol. 12, no 4, 2007, pp. 258 - 261.
[13] R. F. Saen, "A new mathematical approach for suppliers selection: Accounting for non-homogeneity is important," *Applied Mathematics and Computation*, vol. 185, no.1, 2007, pp. 84-95.
[14] A. J.Ruiz-Torres, F. Mahmood, and A. Z. Zeng, "Supplier selection model with contingency planning for supplier failures," *Computers & Industrial Engineering*, vol. 66, no. 2, 2013, pp. 374-382.
[15] K. Patra and S.K. Mondal, "Multi-item Supplier Selection Model with Fuzzy Risk Analysis Studied by Possibility and Necessity Constraints", *Fuzzy Information and Engineering*, vol. 7, no. 4, 2015, pp. 451-474.

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